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Review

COFFEE LEAF RUST (*Hemileia vastatrix*) (characteristics, life cycle, symptoms and control)

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Minireview

A significant loss caused by coffee leaf rust translates to substantial economic losses for coffee producers, including Indonesia. *Hemileia vastatrix* is a biotrophic organism (a parasite that feeds on living cells), otherwise known as obligates, where this parasite can only grow and reproduce on living tissues. Leaf rust disease often attacks coffee plants, especially in Arabica coffee grown in the lowlands. It is not only production land but also during the nursery period; even the disease can also attack leaves on plants that are generated from resistant clones, causing loss. In coffee plants, leaf rust (*Hemileia vastatrix*) can only attack through the stomata on the underside of coffee leaves. Leaf rust disease is characterized by the appearance of yellow to orange spots named urediniospores, located on the underside of the leaves. The control of leaf rust can be through cultural techniques, mechanical and biological.

Keywords*:* leaf rust, biotrophic organism, urediniospores

I. Coffee Leaf Rust

Leaf rust disease, a long-standing threat to coffee plants, has been caused by the fungus *Hemileia vastatrix* since 1876 in Indonesia. This persistent disease has led to a significant decrease in coffee productivity, with some estimates suggesting a reduction of up to 25% (Siregar *et al*., 2022). This reduction in yield translates to substantial economic losses for coffee producers. The widespread existence of this leaf rust disease has resulted in yield losses in all coffee-producing countries, including Indonesia. The damage and yield loss caused by leaf rust disease on coffee plants were already reported in the 1880s, with most Arabica coffee plantations being affected. Even today, this disease remains an ongoing and significant problem in all coffee-producing regions in Indonesia, reducing production by 20%-70% (Harni *et al*., 2015).

The fungus *Hemileia vastatrix* significantly impacts the quality and quantity of plant growth and coffee yields. The development of this plant disease is influenced by three factors: pathogens, hosts, and plants. In the tropics, *Hemileia vastatrix* survives as Uredospora (rust fungus spores), uredium (udospora-producing fruit bodies), and mycelium (a collection of rust fungus hyphae) on diseased leaves to continue infection in plants. Of these fungal structures, uredospores play the most role in developing leaf rust disease (Siska *et al*., 2018). Leaf rust disease often attacks coffee plants, especially in Arabica coffee grown in the lowlands.

Leaf rust attacks not only production land but also during the nursery period; leaf rust disease can also attack leaves on plants that come from resistant clones, causing loss (Talinhas, 2016).

Environmental factors that affect the development of coffee leaf rust disease include temperature, air humidity, rainfall, and sunlightLeaf rust disease, caused by the fungus *Hemileia vastatrix*, has been a persistent threat to coffee plants since 1876 in Indonesia. This disease has led to a significant decrease in coffee productivity, with estimates suggesting a reduction of up to 25% (Siregar *et al*., 2022). It has resulted in yield losses in all coffee-producing countries, including Indonesia. The damage and yield loss caused by leaf rust disease on coffee plants were reported as early as the 1880s, with most Arabica coffee plantations being affected. Even today, this disease remains a significant problem in all coffee-producing regions in Indonesia, reducing production by 20%-70% (Harni *et al*., 2015).

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II. Characteristics of leaf rusts

Leaf rust disease is characterized by the appearance of yellow to orange spots on the underside of the leaves. These spots will appear orange powder, interfering with photosynthesis and plant growth. A further symptom of this disease attack is the large number of leaves that fall off, which decreases the number of flowers and coffee beans produced. *Hemileia vastatrix* is an obligate parasitic fungus, which means that the fungus cannot live on abiotic tissues. This causes the transmission of leaf rust disease to only infect plants around the disease host (Harni *et al*., 2018).

Hemileia vastatrix is a biotrophic organism (a parasite that feeds on living cells), otherwise known as obligates, where this parasite can only grow and reproduce on living tissues.

The coffee species most susceptible to this pathogen is arabica coffee. The reproductive structure of the fungus is uredospora (sexual reproduction), which is their means of reproduction and dispersal. This structure is kidney-shaped and rough in the upper and smooth part of the abdomen (Harni *et al*., 2018).

III. The life cycle of leaf rust

Hemileia vastatrix is a type of hemicyclic fungus that produces urediospores, teliospores, and basidiospores. Urediospores represent the asexual reproductive cycle and infect coffee leaves with favourable environmental conditions. This pathogen can only attack through the leaf mouth or stomata on the underside of coffee leaves (Talinhas *et al*., 2017).

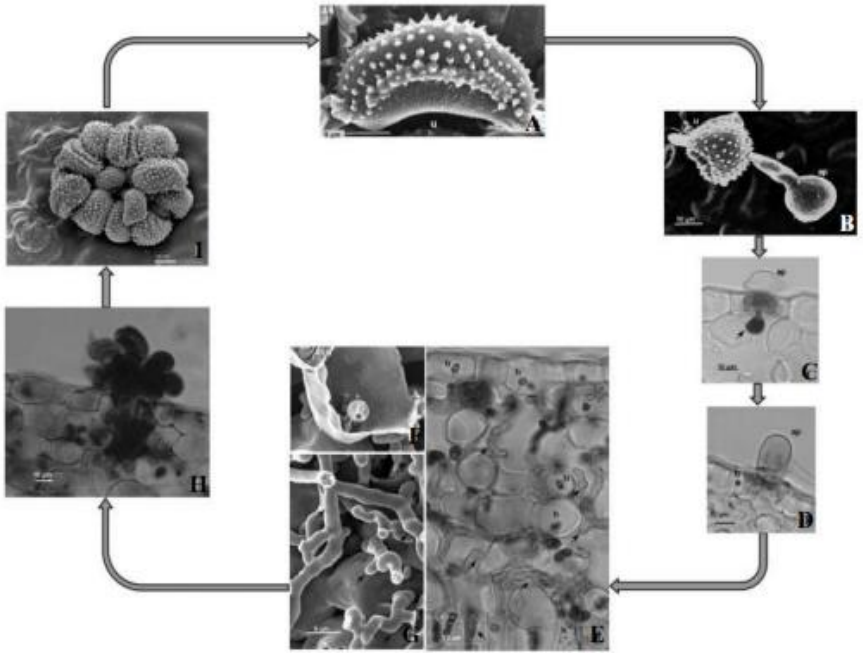

Figure 1. Scanning electron microscope image of *Hemileia vastatrix* infection stage (Source: Talinhas *et al*., 2017)

The infection begins with urediospores forming germination structures and then forming an appressorium in front of the stomata to penetrate the leaf tissue. Germination of urediospores requires water and optimal conditions at around 24 C^0. Once the appressorium is formed, the fungus penetrates the host through the stomata, forming penetrating hyphae that grow into the sub-stomata space. These hyphae will produce two thick lateral branches resembling anchors, a characteristic of *Hemileia vastatrix*. Each lateral branch of the anchor differentiates into haustorial stem cells (HMCs) that form the haustorium, attacking the stomata daughter cells. The fungus continues to grow, producing more inter-cellular hyphae, including haustorial stem cells, and many haustoria will spread within the parenchyma cells of coral flowers and palisades, as well as the upper epidermis. At this stage, the symptoms of chlorosis can be seen. Hyphae attack the cavity of the substomata and multiply. About three weeks after infection, urediospores protrude through the stomata in orange-coloured spots, characteristic of the disease (Talinhas *et al*., 2017).

IV. Symptoms of attack

According to Hulupiet *et al*. (2012), leaf rust disease has typical symptoms. On the underside of the leaves, some spots are initially light yellow and then turn dark yellow. Next, bright orange flour is formed, which consists of urediospores of the disease-causing fungus. The old spots are dark brown to black and dry. Severely affected leaves will dry and fall off, making the plant barren. This disease can cause infected leaves to fall off prematurely (Navarro *et al.*, 2024).

An increase in spots on the leaves can cause them to fall off more easily. Leaf rust disease weakens the plant, which may lead to overbearing. This condition can result in a depletion of starch reserves in the roots and twigs, potentially leading to the tree's death. The plant's weakened state can also reduce yields in the following year, even if the disease does not present immediately. As a result, losses caused by *Hemileia vastatrix* can be challenging to quantify, as they are cumulative and can persist for up to one or two years after an initial attack (Castillo *et al*., 2022).

Figure 2. Symptoms of leaf rust attack in coffee leaf
(Source: Research documentation; the black circle shows developed urediniospores)

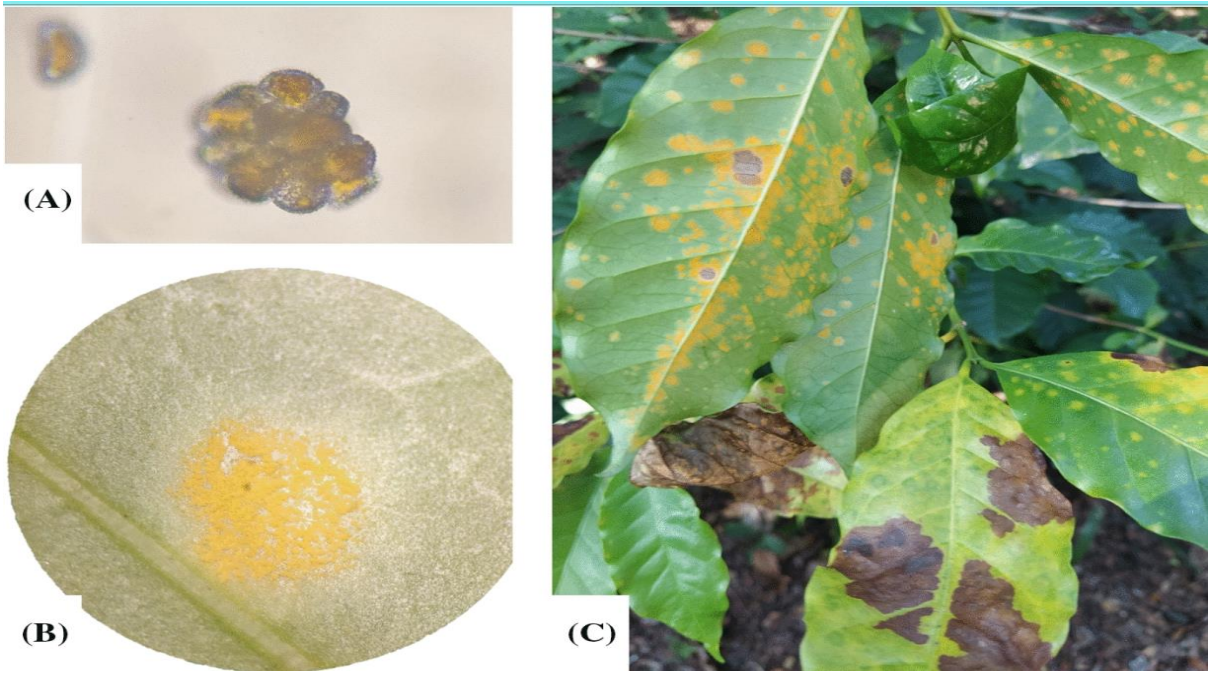

Figure 3. A: Urediospores; B and C: developed urediniospores in the leaf
(Source: Talinhas et al., 2014; Salazar *et al*., 2024;

V. Leaf rust control

Controlling leaf rust disease in coffee using resistant varieties can be unsuccessful over time due to the high adaptability of *Hemileia vastatrix*, which can develop strains that overcome previously resistant coffee plants. This issue is particularly pronounced when resistant varieties are planted continuously over large areas, promoting the emergence of new strains of the fungus. In Indonesia, more than eight physiological races of *Hemileia vastatrix* exist.

1. Biological Control

Biological control is a method of managing diseases by leveraging natural enemies. The fungus Verticillium is a hyperparasite, targeting other parasitic fungi involved in coffee leaf rust disease. When the uredospores of *Hemileia vastatrix* are parasitized by Verticillium, their growth is disrupted, leading to their death. This process is marked by white growth from the Verticillium fungus in the area affected by the rust symptoms.

2. Technical control of the practice/culture

The Center for Research and Development of Plantation (Puslit Koka) has developed technical recommendations for coffee cultivation. These recommendations include several vital practices:

a. Regular weeding.

b. Apply organic fertilizer, including Nitrogen, Phosphate, and Kalium, twice a year, specifically at the beginning and end of the rainy season, adjusting the dosage according to the plants' age.

c. Pruning after harvest includes removing unproductive shoots or branches and eliminating water shoots.

d. Managing the intensity of shade. Properly implementing these cultural practices can reduce damage to coffee plants caused by leaf rust by up to 64% and increase production by 80% (Center for Research and Development of Plantation, 2014).

3. Chemical Control

This refers to using chemicals to manage pests, diseases, or unwanted plants in agriculture and other sectors. Implementing chemical control can help maintain crop health and productivity while minimizing damage. However, using these chemicals responsibly and by safety regulations to protect the environment and human health is essential. Leaf rust disease is challenging to manage, making fungicides the preferred choice for control. As of the year of 2005, there are 11 active fungicide ingredients were recommended for managing leaf rust in coffee plants in Indonesia. These include proconazole, hexaconazole, triadimefon, triadimenol, benomyl, copper oxychloride, mancozeb, copper hydroxide, copper oxide, difenoconazole, and propiconazole (Siska, 2018).

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